Optimization of Placing Viscous Dampers on 3D RC Frame Subjected to Seismic Loading

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Abstract - *Earthquakes are one the world's most deadly natural hazards. Large earthquakes often strike without warning, leading to catastrophic effects. The National Earthquake Information Centre (NEIC) archives an average of 20,000 earthquakes every year (approximately 55/day) around the world.*

RC frame structures being most common, on seismic loading will have large impact to its elements. Since, there are fundamentally two ways to improve the seismic performance of these structures. One method is to improve the deformation capacity of structural members like beams, columns etc., which is not always possible in practical situations. Another method is to add retrofitting techniques like dampers or base isolators to increase the seismic performance of the structures.

Adding dampers to the structures, in order to reduce seismic responses is not only found effective but also economical in some of the constructions. Hence, in this dissertation work the efficiency of diagonal and chevron type viscous damper on 3D-RC frame is assessed based on placement of the dampers at various locations. Then response spectrum analysis is carried out here to study the dynamic behaviour of the structure. It is concluded that the base shear is reduced when placed at corners of bottom half storey. It is also observed that it is lesser when placed at center columns than at alternating one and is vice versa for the latter one.

Key Words: modal analysis, equivalent static analysis, response spectrum, dampers, etabs

1. INTRODUCTION

In recent years, earthquake-resistant design and retrofitting of structures with energy absorption systems have received a lot of attention. Viscoelastic (VE) dampers have proved to be capable of delivering significant additional dampening to structures in order to dissipate seismic energy. Comprehensive experimental and analytical research on the use of viscoelastic dampers have demonstrated that these dampers are particularly successful in minimising structural vibration at all environmental temperatures during mild and large earthquake ground motions. With the use of VE dampers, the ductility demand of structures can be greatly lowered. Many important developments in seismic codes have been discovered in the recent few years. The majority of the changes in the seismic design field arise from a growing awareness of actual poor structural performance in earthquakes.

Viscous dampers are a type of passive energy dissipation device that is used to increase the effective stiffness of new and existing structures. They're made of a tough material, and energy is transferred by the piston and absorbed or dissipated by the silicone-based fluid that flows between the piston and cylinder assembly.

"Three methods are commonly used to classify structural control systems. Active energy dissipation, semi-active energy dissipation, and passive energy dissipation are the three types of structural control systems. Devices that are utilised to dissipate the seismic effect are known as passive energy systems. The fundamental purpose of passive devices is to absorb a portion of seismic energy (input energy), reduce earthquake energy or force on structural elements, and reduce the proportion of structural damage. In contrast to semi-active or active systems, passive control systems do not require external power. The active control system is tunable and requires some external power to operate. The sensor attached to the structure will be used by the active control system."[1]

1.1 Objectives of Present Study

a. Performance analysis of 3D-RC bare frame under seismic loading.
b. Relative comparison between different configurations of models based on location and number of dampers.
c. Evaluation of optimised configurations of the models.
d. Concluding the variation in response of various configurations

2. METHODOLOGY

Comprehensive literature review is carried out on the seismic response of 3D RC frames with viscous damping
3D RC frames with G+9 stories and with different configurational the location of viscous dampers is considered.
FE analysis involving Modal, Equivalent Static and Response Spectrum analyses are considered. The results obtained are time period, mode shape, displacement, storey drift, base shear and acceleration. All the results are tabulated, discussed and conclusions are drawn.

2.1 DESIGN DATA:

Model G+9 with each storey height 3m is considered. The model has 5 bays in both the horizontal plane each of 4m width. Thus, the total plan area will be 400 sq. meters.

Table -1: Modelling details

Type of structure	Special moment resisting RC Frame
Grade of concrete	M 25 (fck=25N/mm^2)
Grade of reinforcement	Fe 500(fy=500 N/mm^2)
Height of building	30m, G+9
Each floor height	3
Number of stories	G+8
Column size	600X600mm
Beam size	300*450mm
Slab thickness	150mm
Density of concrete	25KN/m^3
Live Load on roof	2.5 kN/m^2
Live Load on Floor	2.5 kN/m^2
Floor finish	1 kN/m^2
Zone	2, 5
Response reduction factor	5

The two configurations of Fluid Viscous Dampers (FVD) with data that can be used for modelling in ETABS 2019.

1. Fluid viscous dampers & lock-up device's clevis - clevis configuration.

2. Fluid viscous dampers & lock-up device's cheveron type configuration.

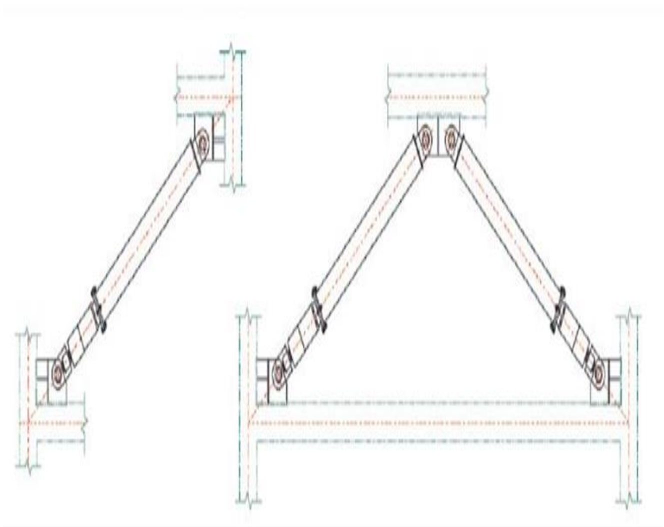

Fig -1: Fluid viscous dampers

Table -2: Details of FLUID Viscous damper

Damper notation	Mass (Kg)	Coefficient (KN-s/m)	Exponent	Stiffness (KN/m)
FVD	44	300	0.3	25000

DESCRIPTION OF THE MODELS:

The studies are concerned to IO different configurations of G+9 storey building under seismic zone II and V.

The models considered in this dissertation work are tabulated in table below

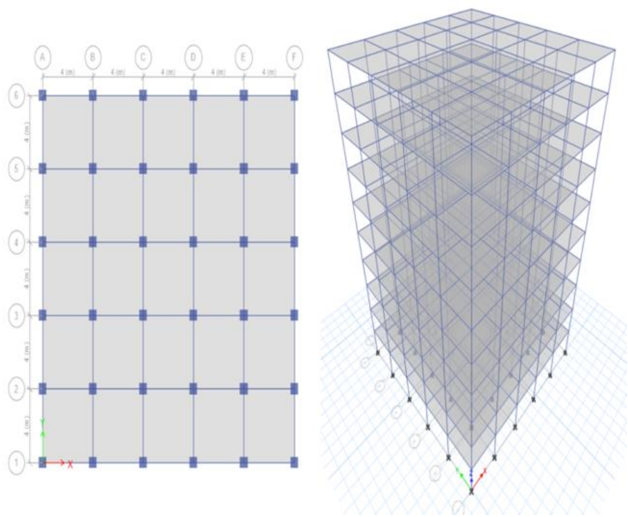

Fig -2: RC Bare Frame Model

2.2 LOAD COMBINATIONS:

Given design load combinations for RC framed structure in ETABS are.

- DL+LL+FF
- DL+LL+FF+EQ (for static analysis)
- DL+LL+FF+RS (for response spectrum analysis)

The comparison has been made between the structure without damper and structures with dampers. A G+9 storey structure with 10 different configurations based on the placement of dampers are considered

M – Middle column, T – Even column, S – Single damper,

I – Inverted double damper, FC - Column, C- Corners

model	Details	NOMENCLATURE
1	RC bare frame	BF
2	RC bare frame, dampers in middle column, single all storeys	BMFCS
3	RC bare frame, dampers in middle column, double all storeys	BMFCI
4	RC bare frame, dampers in middle column, single bottom half storeys	BBHMS
5	RC bare frame, dampers in middle column, double bottom half storeys	BBHMI
6	RC bare frame, dampers at even column, single all storeys	BTAS
7	Rs bare frame, dampers at even column, double bottom half storeys	BTBHI
8	RC bare frame, dampers in middle column, single top half storeys	BMTHS
9	RC bare frame, dampers in middle column, double top half storeys	BMTHI
10	RC bare frame, dampers at corners, single in all storeys	BACS

2.3 RESULTS AND DISCUSSIONS

The important parameters under consideration are listed below.

- Fundamental time period
- Base reaction
- Displacements
- Acceleration
- Storey drift

2.3.1 FUNDAMENTAL TIME PERIOD

Modal analysis characterizes the seismic properties of an elastic structure by identifying its mode of vibration. The response of the structure is different at each of the different natural frequencies.

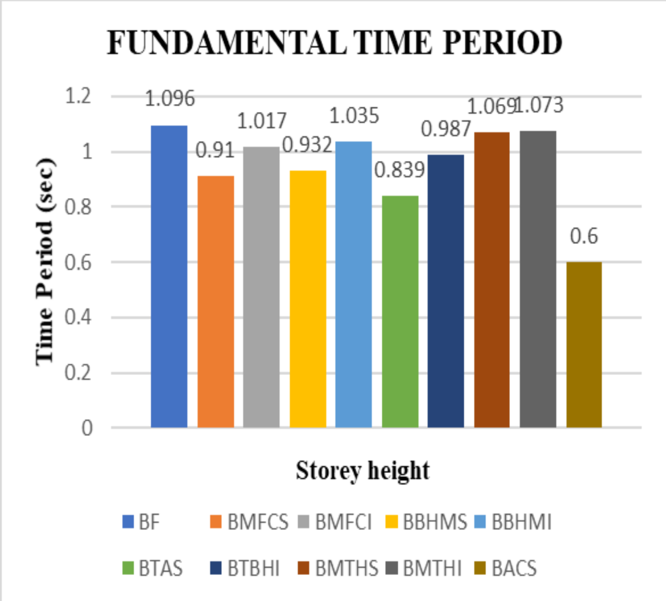

Chart -1: Fundamental time period.

Time period of the bare frame structure is found; reduced when dampers are added to the structure.

The time period obtained from the modal analysis does not match with time period from codal formulae therefore provisions have to made in the code for the better results.

2.3.2 BASE SHEAR

The building with more seismic weight will be having high base shear and low time period.

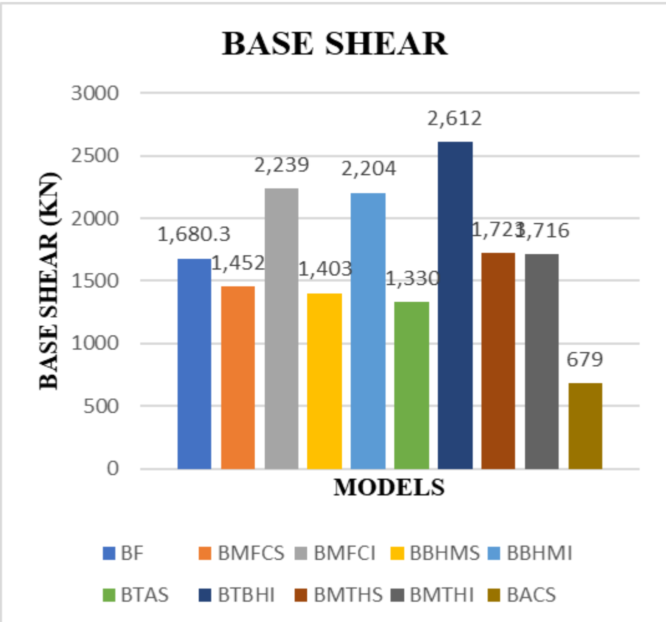

Chart -2: Base Shear

Dampers when installed at the bottom half of the structure, shear force is found to be effectively shared by the dampers within the structure.

2.3.3 MAXIMUM DISPLACEMENT

Displacement of structure is referred to lateral displacement at the top of frame. Due to inertia caused by lateral force the displacement is referred as lateral displacement. Displacement will be minimum at the base and maximum at the top of frame. Displacement of the structure increases with increase in height of the structure.

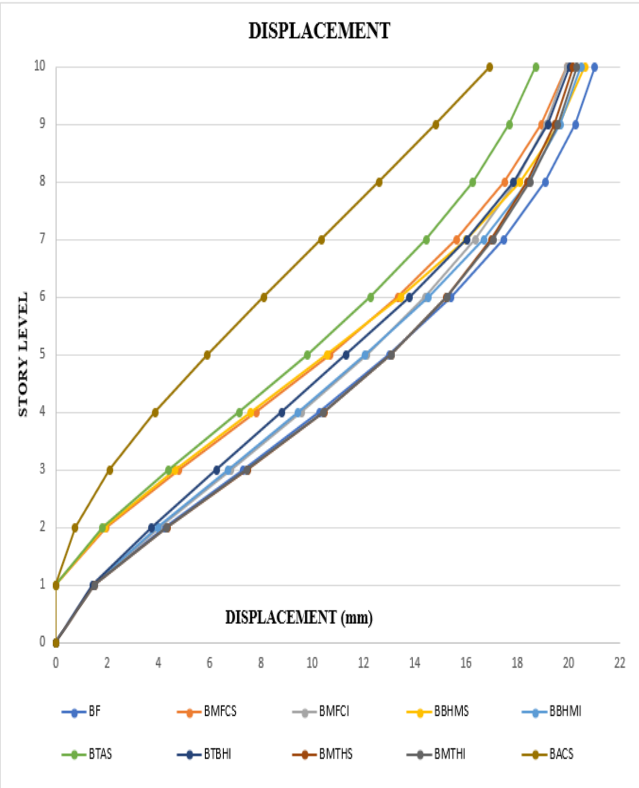

Chart -3: Displacement curve of G+9 storey building

Below figure shows the maximum displacement graph of all the models under zone V

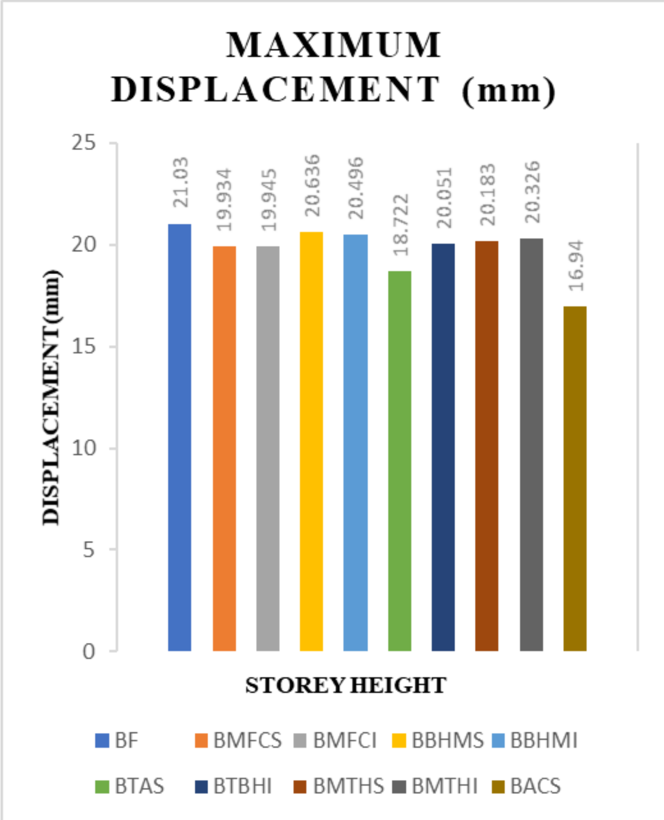

Chart -4: Maximum Displacement

2.3.4 ACCELERATION:

In order to study the dynamic behaviour of the structure, acceleration is one of the important factors under consideration.

Due to the Maxwell modelling of dampers, the stiffness of the structure is increased. Thus, frequency of the structure increases. As the frequency increases the fundamental time period decreases leading to an increase in the acceleration.

It is observed even in the models under consideration that the acceleration of the structures with dampers is higher than the structures without dampers.

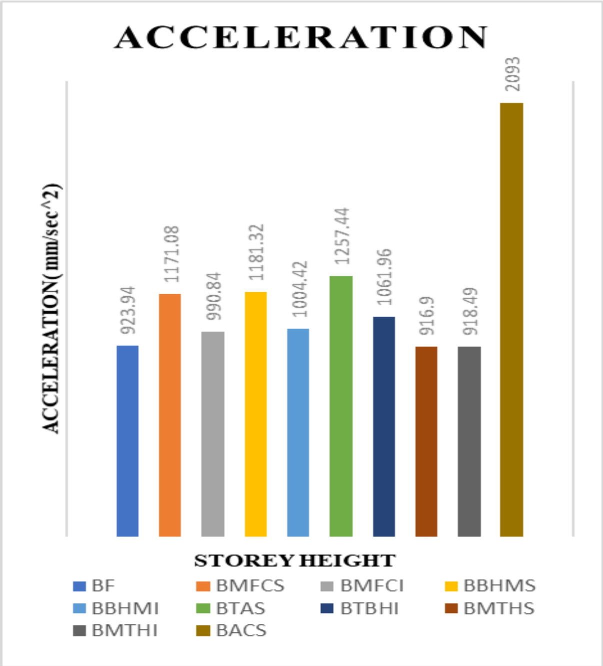

Chart -5: Maximum Acceleration

2.3.5 STOREY DRIFTS:

According to IS 1893(Part 1):2016 clause7.11.1, the storey drift is the displacement of one level relative to the other level above or below. Chart 6 shows storey drift graph of G+9 storey building. And all the values are tabulated.

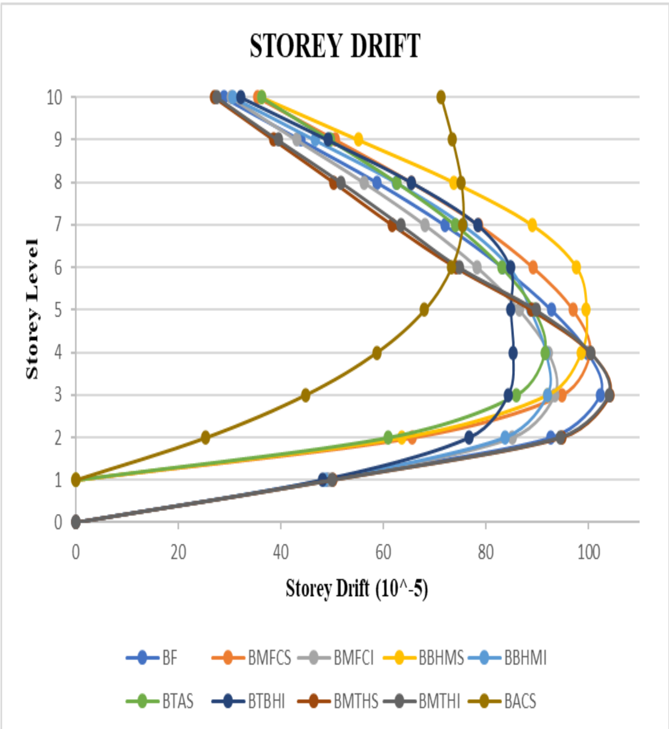

Chart -6: Drifts curves of G+9 storey building

The storey drift is appreciably reduced in BACS (bare frame dampers at the entire storey height single) configuration.

3. CONCLUSIONS

The seismic behaviour of the reinforced concrete structure is judged by analysing parameters such as displacement, storey drift, acceleration, base shear and fundamental time period. All the results are well within permissible limits. The following conclusions can be made based on the analysis carried out.

1. Time period of the bare frame structure is found to be reduced when dampers are added to the structure. Since the time period determined by modal analysis differs from the time period determined by codal formulae, modifications must be included in the code for better results.

2. Structures where the dampers are at the corner storey full (BACS) have shown significant reduction in the value of time period. This Model (BACS) has shown about 45.25% reduction in the value of time period.

3. The base shear of the bare frame structure is found to be reduced when the structure is stiffened at the base and or at the bottom half of the structure.

4. Base shear of two models (BMTHI and BTHS) where the dampers are placed at the top half of the structure is not effective in the reduction of value since mass is significant at the top.

5. In comparison between BTAS and BACS, the base shear value of BACS (dampers at All corner) is quite lesser than BTAS (dampers at the even column, entire storey height) though it has same number of dampers.

6. In terms of placing and positioning, Base shear for single dampers in middle column BMFCS is grater when compared to dampers placed at even column BTAS.

7. Base shear for double dampers in middle column BBHMI is greater when compare to dampers placed at even column BTBHI.

8. It is concluded that base shear at corners bottom half is least but as for middle column it is less than placed at even column for single dampers and vice versa for double dampers.

9. In case of bare frame structure there is about 19.4% reductions in the displacement response when dampers are installed at all the floors in the corner for G+9 storey building.

10. BACS model is stiffer when compared to other configurations hence they show higher acceleration value by 126.53% when compared to bare frame model.

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